

Glass



Glass Annual Report Fiscal Year 2003

Industrial Technologies Program

Boosting the productivity and competitiveness of U.S. industry
through improvements in energy and environmental performance



U.S. Department of Energy
Energy Efficiency and Renewable Energy

Industrial Technologies Program — Boosting the Productivity and Competitiveness of U.S. Industry

Industry consumes 33 percent of all energy used in the United States. By developing and adopting more energy efficiency technologies, U.S. industry can boost its productivity and competitiveness while strengthening national energy security, improving the environment, and reducing emissions linked to global climate change.

The U.S. Department of Energy’s (DOE) Office of Energy Efficiency and Renewable Energy (EERE) works in partnership with U.S. industry to increase the efficiency of energy and materials use, both now and in the future. Through an innovative strategy known as Industries of the Future (IOF), EERE’s Industrial Technologies Program (ITP) seeks to improve the energy intensity of the U.S. industrial sector through a coordinated program of research and development (R&D), validation, and dissemination of energy efficiency technologies and operating practices. ITP develops, manages, and implements a balanced portfolio that addresses industry requirements throughout the technology development cycle. The primary long-term strategy is to invest in high-risk, high-return R&D. Investments are focused on technologies and practices that provide clear public benefit but for which market barriers prevent adequate private-sector investment.

The IOF strategy maximizes the energy and environmental benefits of ITP’s process-specific technology investments by forming collaborative partnerships with energy-intensive industries. These collaborations aim to effectively plan and implement comprehensive R&D agendas and help disseminate and share best energy management practices throughout the United States. The IOF public-private partnerships also facilitate voluntary efforts, such as the President’s Climate VISION initiative, to encourage industry and government to reduce greenhouse gas emissions. ITP focuses its resources on a small number of energy-intensive materials and process industries that account for over 75 percent of industrial energy consumption:

- Aluminum
- Chemicals
- Forest Products
- Glass
- Metal Casting
- Mining
- Petroleum Refining
- Steel

ITP also conducts R&D projects on enabling technologies that are common to many industrial processes such as industrial energy systems, combustion, materials, and sensors and process control systems. In addition, ITP funds technical assistance activities to stimulate near-term adoption of best energy-saving technologies and practices within industry. These activities include plant assessments, tool development and training, information dissemination, and showcase demonstrations.

New technologies that use energy efficiently also lower emissions and improve productivity. By leveraging technical and financial resources of industry and government, the IOF partnerships have generated significant energy and environmental improvements that benefit the nation and America’s businesses. Energy-intensive industries face enormous competitive pressures that make it difficult to make the necessary R&D investments in technology to ensure future efficiency gains. Without a sustained commitment by the private and public sectors to invest in new technology R&D and deployment, the ability to close the gap between U.S. energy supply and demand will be severely compromised.

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EXECUTIVE SUMMARY—GLASS INDUSTRY OF THE FUTURE

Today, the glass industry faces significant challenges in maintaining its competitive standing in global markets. Competition from developing countries where energy and labor are cheaper is putting pressure on U.S. producers. These conditions are exacerbated by the increasing volatility of domestic energy prices and supplies. Growing societal demands for environmental stewardship, and demand for shorter-term returns on investment continue to impact the availability of R&D funds, especially for basic and applied research. Productivity improvements and economic weakness have led to workforce reductions in the industry. These challenges have led to a major change in this highly competitive industry. Companies are now more willing to collaborate in strategic, pre-competitive areas to reduce costs, environmental impacts, and energy use.

The U.S. glass industry is a significant consumer of energy in the manufacturing sector, using an estimated 254 trillion Btu of energy in 1998. More importantly, the high proportion of energy costs (between 15 and 20 percent, depending on segment) as a percent of direct production costs in the industry makes the glass industry a prime target for energy efficiency R&D. Increasingly stringent environmental regulations associated with the combustion of fuels, used primarily for process heating in the glass industry, and the growing volatility of energy markets are making investments in energy efficiency R&D more attractive. In addition, the glass industry's fuel of choice, natural gas, has encountered two major price spikes since the beginning of the decade. Furthermore, our growing dependence on imported energy threatens our national energy security and makes a strong case for reducing the use of energy.

Significant advancements in melting technology are needed to revolutionize the way energy is used in glass manufacturing. Energy consumed in the manufacturing of glass products is generally two to three times the theoretical minimum. More efficient process heating technology can significantly reduce the use of fuels and electricity required for glass processing.

A Successful Partnership with Industry

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) leads the federal role in developing advanced energy efficiency and environmentally friendly industrial technologies. Glass industry R&D is a component of the overall EERE strategy and contributes to the goals outlined in the National Energy Policy. Improving energy efficiency in glass manufacturing as well as improving glass products will reduce the energy intensity of industry and could directly reduce the amount of petroleum imported into the United States, two of EERE's top priorities.

The Glass IOF will help the glass industry achieve a 50 percent reduction in the gap between 1995 melting energy use and the theoretical minimum by 2020.

The EERE Industrial Technologies Program implements the Glass Industries of the Future (IOF) effort, which seeks to boost efficiency and productivity of the energy- and resource-intensive glass industry by investing in a balanced R&D portfolio with broad applicability in furnace operations. The Glass IOF works in partnership with the Glass Manufacturing Industry Council, an organization representing the technology needs of the U.S. glass industry. The groups comprising the partnership work with industry, academia, national laboratories, and others to promote technology development of more environmentally sound energy efficiency technologies. By partnering, the Glass IOF leverages public and private resources and ensures the application of research results.

Achieving Energy Savings: Portfolio Strategy

The Glass IOF supports a portfolio of cost-shared, pre-competitive research addressing key technological needs that have broad applicability throughout the glass industry. The strategy fosters both revolutionary technologies and incremental improvement to existing processes, thereby addressing long-term goals without neglecting short-term opportunities to improve energy efficiency. As the Glass IOF shifts toward supporting a smaller number of riskier and more costly high-impact projects, research activities are organized into the following categories: next generation melting systems, energy efficiency performance improvements, advanced processing and environmental R&D, and technology deployment. The FY 2003 Glass Portfolio

included 13 R&D projects. Many other projects funded by EERE are applicable to the glass industry. More information about the Glass IOF portfolio is available on the Industrial Technologies Program Web site at www.oit.doe.gov/glass.

FY 2003 Highlights

- **Three New Awards Underway** - Three new projects were negotiated and awarded through a competitive solicitation. Two of the three new awards are high-risk projects that involve developing innovative glass melting techniques that could significantly reduce energy and capital requirements. All three projects have been initiated.
- **Technology Transfer Efforts for Advanced Glass Furnace Model Begin** - Validation studies on the second version of the glass furnace model developed by Argonne National Laboratory continued at five participating companies. The more robust, final version of the code is now operational, and additional validation studies are being conducted. A technology transfer workshop was held to introduce the code to the glass industry, and licensing discussions have also been conducted.
- **High-Luminosity, Low-NO_x Burner Undergoes Additional Field Testing** - Commercial-scale versions of the high-luminosity, low NO_x burner developed by the Gas Technology Institute and Combustion Tec underwent long-term evaluation. An oxy-fuel fired fiberglass furnace was fully outfitted with several of the commercial-scale burners. In addition, another long-term test is ongoing on an oxy-fuel fired flat glass furnace fully outfitted with the burners through a National Industrial Competitiveness through Energy, Environment, and Economics (NICE³) grant. While detailed results are not yet available, performance has predominantly met expectations for energy savings and emissions reductions. The burner should be commercially available in FY 2004.
- **Allied Partnership Signed with GMIC** - An Allied Partnership agreement was signed with the Glass Manufacturing Industry Council (GMIC) in June 2003. This agreement formalizes a relationship between DOE and GMIC that will lead to the implementation of numerous energy improvement technologies and techniques across the glass industry. The GMIC has already hosted two energy efficiency training workshops, one on compressed air and the other on process heating.
- **Furnace Energy Assessment Best Practice Recently Developed** - An energy assessment best practice protocol for oxy-fuel firing optimization is nearing completion. Measurements have been completed and data analysis is underway. Several opportunities have been identified that can help optimize furnace operations and reduce energy consumption.
- **Resource CD-ROM Released** - An updated resource CD-ROM for glass manufacturers was released. The CD-ROM provides tips and tools for spotting energy-saving opportunities in glass plants today, as well as details on energy efficiency technologies.

Additional research and partnership highlights can be found in Section 3, FY 2003 Highlights and Accomplishments.

GLASS INDUSTRY OVERVIEW

Glass is an integral part of the American lifestyle and a staple of the nation's economic success. Its popularity as a material stems from its transparent, durable, recyclable, and nonpermeable qualities. The U.S. glass industry is comprised of four major segments based on end products:

- Container glass (bottles, jars, packaging)
- Flat glass (windows, automobile windshields, picture glass)
- Fiberglass (insulation fiberglass, optical fibers, textile fibers)
- Pressed and blown glass (television tubes, light bulbs, table and ovenware, scientific and medical glassware)

The U.S. glass industry employs over 140,000 workers at approximately 2,500 facilities throughout the nation, including workers from a fifth glass industry segment, products of purchased glass. This segment includes items such as mirrors, ornaments, art glass, and aquariums.

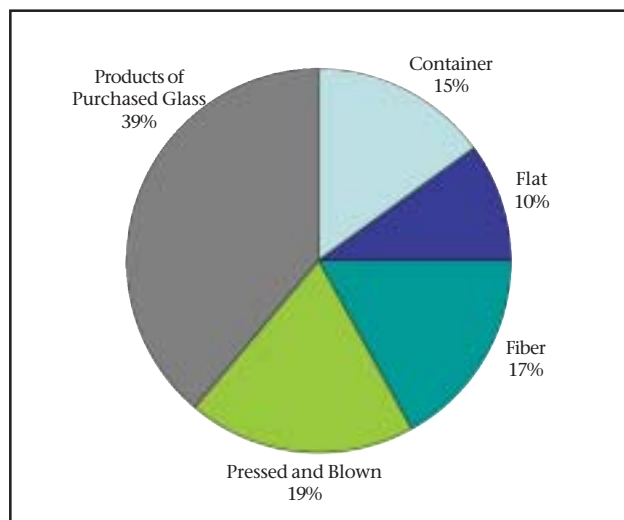
Competitive global markets and technological change have led to accelerated restructuring, joint ventures, mergers, and acquisition activities throughout the industry. Glass companies today are often diversified into other related products, such as ceramic, packaging, and building materials, and other higher margin products. Glass companies rely on technology, science, and innovation to create value-added products and gain ground in new markets. However, large capital investments are required to keep glass manufacturing plants operating at a competitive level. U.S. glass companies' products compete with both foreign sources and, in many segments, other materials such as plastics and metals.

While all glass product segments have melting in common, there are both real and perceived differences in which types of melting satisfy their individual business needs, such as production rate and compositional flexibility. Another key attribute is glass quality, and requirements vary from sector to sector. The most significant quality parameter between sectors is the amount of small gaseous inclusions, called seeds, which are allowed to remain in the molten glass. Seeds influence the aesthetics and service performance of glass products. For example, customers would not tolerate bubbles in auto windshields, but would not care about imperfections in residential insulation fiberglass.

Glass Industry Shipments and Trade

In 2001, U.S. glass industry shipments totaled nearly \$28 billion. Exhibit 1 shows the value of shipments for the major sub-sectors. Products of purchased glass lead the industry in shipments with 39 percent of the total, followed by pressed and blown glass (19 percent), mineral wool/fiber (17 percent), container glass (15 percent), and flat glass (10 percent). Over the last decade, the industry has grown at an average rate of about 1 to 2 percent per year, with highest growth rates in the flat and fiberglass segments. During the 1990's, industry consolidation continued and high-value niche industries such as fiber optics and glass for electronics began to gain market share. Along with consolidation has come an increase in foreign ownership. Today, the U.S. industry has fewer major players in most industry segments. While commodity glass products continue to form the core of the industry, the highest future growth is predicted to occur in specialty applications. The U.S. glass industry has generally maintained a small trade deficit (around 1-2 percent of net shipments). Annual production of the U.S. glass industry is approximately 20 million tons. Production of container and flat glass is estimated to be about 9 million tons and 5 million tons, respectively.

Exhibit 1 Industry Shipments by Segment, 2001



Source: Annual Survey of Manufactures, DOC.

Energy Use

In 1998, energy consumption in the glass industry was estimated at approximately 254 trillion Btu. Energy use in the glass industry is used primarily for process heating. During the last decade, significant improvements have been made in energy efficiency, reducing energy use per unit of output substantially since the early 1970s. Technologies such as advanced burners, improved refractories, and oxy-fuel firing have played a major role in efficiency improvements.

Exhibit 2 shows the glass industry’s energy inputs by source. Natural gas provides the largest share of energy for heat and power. Electricity is primarily used for furnace heating and machine-driven equipment.

The industry spent \$1.8 billion in energy purchases for fuel and power in 2001, a nearly 30 percent increase over energy costs in 1997. The dramatic increases in natural gas prices in 2000 and 2001 have had a substantial negative impact on the industry.

Energy end-use patterns can be illustrated through the use of an energy footprint, shown in Exhibit 3, which identifies both energy use and losses due to equipment and system inefficiencies. Process heating, mostly from glass melting and refining, represents the largest use of fuels in the glass industry (91 percent). About 18 percent of energy delivered to the plant is lost prior to being used in specific processes. Electricity use is primarily split between process heating (43 percent) and motor-driven equipment (41 percent). Technologies that improve the efficiency of process heating systems have significant potential to reduce overall industry energy use.

The total primary energy associated with the glass industry is 372 trillion Btu, which includes energy losses associated with the generation of power at off-site utilities, and the transport of fuels to the plant site. As shown in Exhibit 3, these off-site losses are considerable, amounting to about 118 trillion Btu.

While not estimated by the energy footprint, process operations represent substantial energy sinks where new technology as well as incremental improvements can have an impact. Glass furnaces, for example, the mainstay of the industry, often operate with less than optimal thermal efficiencies.

In theory, only 2.2-2.7 million Btu/ton are required to melt a ton of glass, depending on the composition of the glass. Energy is required for the heat of reaction and enthalpy of glass and gases emitted. However, inefficiencies cause the process to consume considerably more energy than is theoretically required, as much of the heat is lost through furnace walls and exhaust gases. In practice, two or three times the theoretical minimum is consumed during the melting and refining of glass.

Glass Segment Average Melting/Refining Energy Consumption, 1998 (million Btu/ton of glass)

Flat Glass	8.6
Fiber Glass	8.4
Pressed and Blown Glass	7.3
Container Glass	5.5

Exhibit 2 Energy Use in the Glass Industry

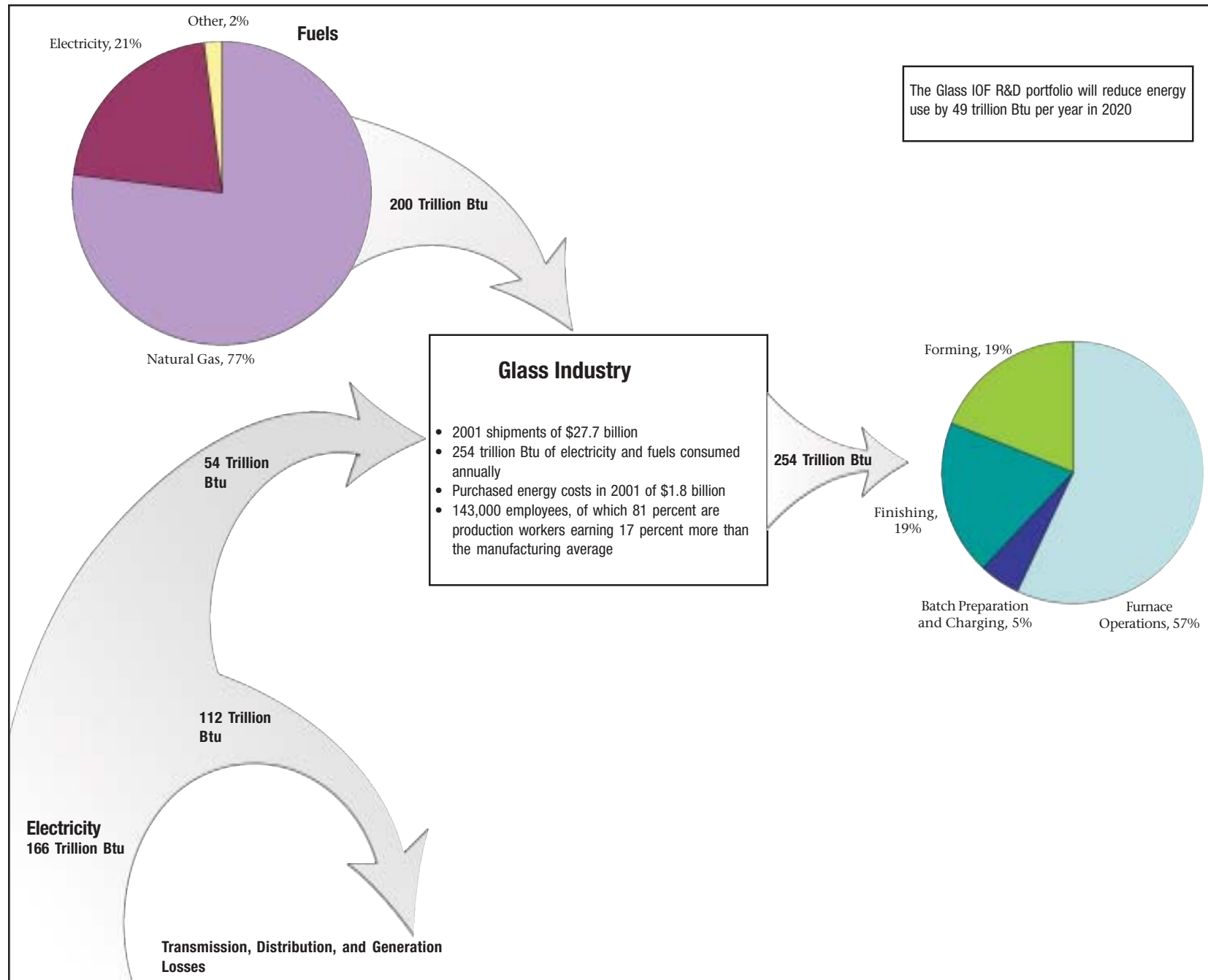
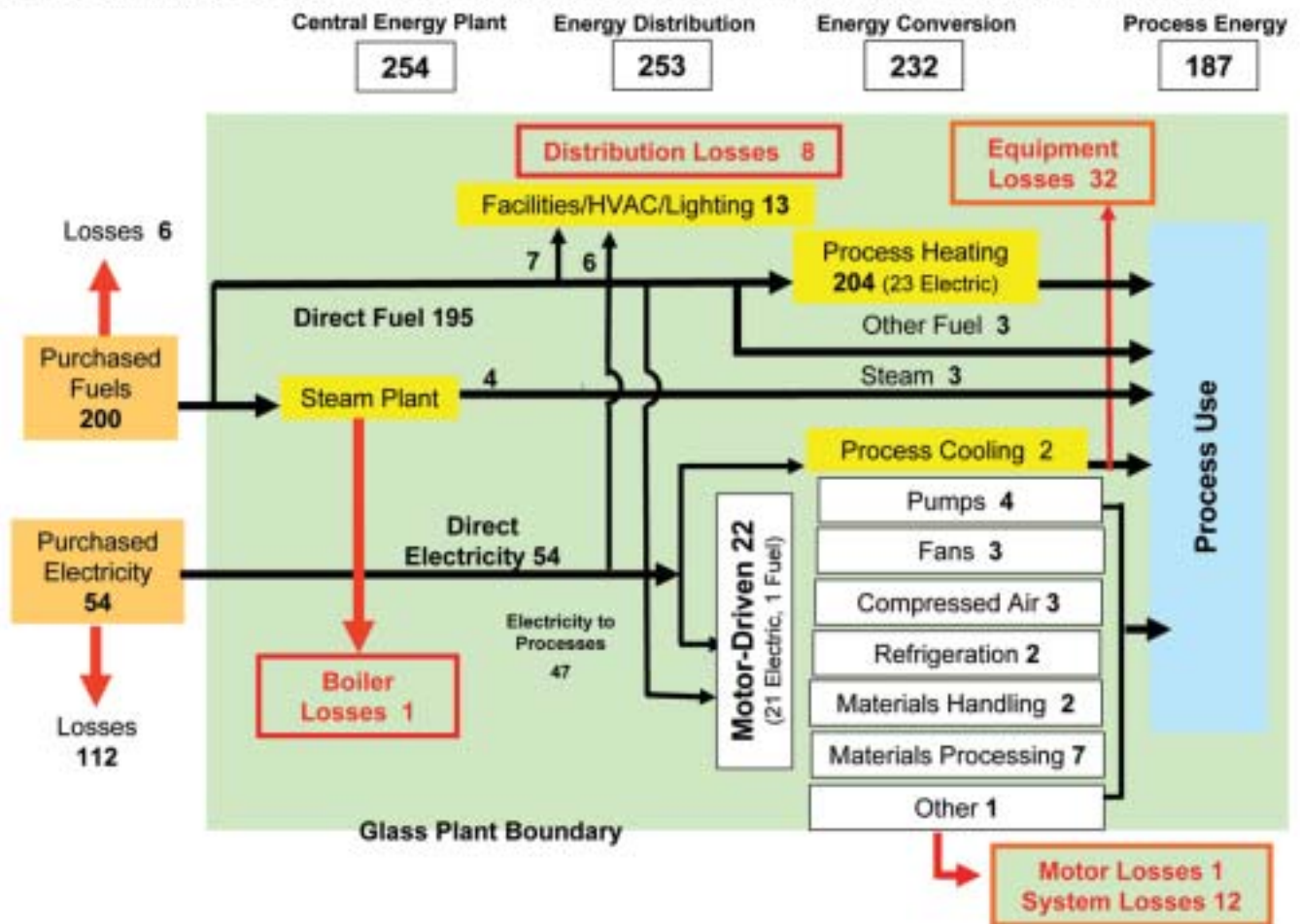


Exhibit 3 Energy Footprint for the U.S. Glass Industry

NAICS 3272 and 3296 Glass & Glass Products, Fiber Glass Total Associated Energy: 372 Trillion Btu



THE CHALLENGE

Glass products are an integral part of the American economy and everyday life. Glass products are used in food and beverage packaging, lighting, communications, transportation, and building construction.

Today, the U.S. glass industry faces significant challenges in maintaining its leadership position in global markets. Competition from developing countries is putting increasing pressure on U.S. producers, particularly countries where energy and labor are cheaper and government subsidies help to fuel new industry with less stringent regulations. Growing societal demands for cleaner production and environmental stewardship continue to place increasing pressure on limited R&D funds. Demand for shorter-term returns on investment in recent years has also limited the amount of capital available for research activities, especially basic and applied research. The workforce in the glass industry has dropped in recent years by more than 5 percent, from 150,000 in 1997 to 143,000 in 2001.

The competitive demands facing glass companies have led to a major change within this highly competitive industry. For the first time in several decades, glass companies are now willing to collaborate in strategic, pre-competitive areas to reduce costs, environmental impacts, and energy use. The industry has emphasized in the *Glass Industry Technology Roadmap* that collaborative partnerships involving government, industry, and academia will be critical to meeting the technology challenges of the future and accelerating the pace of technological innovation. Recognizing that R&D consortia could benefit both industry and the nation, the industry organized the Glass Manufacturing Industry Council, an association of major U.S. glass companies and supporting organizations. This group works with government and academia to promote the development of more environmentally sound energy efficiency glass technologies.

An Energy-Intensive Industry

Energy is a major factor in the technology equation for the glass industry. The U.S. glass industry consumed an estimated 254 trillion Btu of energy in 1998. The magnitude of energy consumed by the industry makes it a prime target for energy efficiency R&D, with potentially large energy savings opportunities. In 2001, energy costs accounted on average for about 19 percent of direct glassmaking production costs. The industry relies primarily on natural gas to provide heating for the manufacture of glass products.

While tremendous advances have been made in energy efficiency since the oil crises of the 1970s, the industry still relies on many processes that are relatively inefficient and energy-intensive. When energy costs are low relative to the costs of processing and other inputs to production, investments in energy efficiency often take a backseat to investments in environmental compliance or product development. However, increasingly stringent environmental regulations associated with the combustion of fuels and the growing volatility of energy markets are moving energy efficiency to the forefront. The record high prices for natural gas over the last two years, for example, have forced plants to close and to move new projects out of North America where natural gas is cheap and plentiful.

The government and the glass industry have overlapping interests for improving energy efficiency. By improving the efficiency of glassmaking, the glass industry benefits by reducing production costs and by becoming more competitive. The government also desires both near- and long-term solutions for reducing domestic energy consumption. Innovative glass products which require consumers to use less energy will also help the United States reduce energy demand. However, permanent technology changes, rather than short-term fixes, are needed to revolutionize the way energy is used in glass manufacturing. Efforts have been initiated to develop a next-generation melting system to significantly reduce energy requirements needed for glassmaking.

Glass industry R&D is a component of the overall EERE strategy to improve energy efficiency and contributes to the goals outlined in the National Energy Policy. Specifically, improving energy efficiency in glass manufacturing will reduce the energy intensity of industry and indirectly reduce the amount of petroleum imported into the United States, two of EERE's top priorities.

Strategy for Improving Glass Industry Energy Efficiency

The U.S. Department of Energy’s (DOE’s) Office of Energy Efficiency and Renewable Energy (EERE) leads the federal role in developing advanced energy efficiency and environmentally friendly industrial technologies. The EERE Industrial Technologies Program implements the Glass Industry of the Future (IOF) effort, which seeks to boost efficiency and productivity of the energy-intensive glass industry.

The Glass IOF responds to the unique challenges in the glass industry by supporting collaborative, innovative R&D improvements in process technologies and design tools and methodologies; promoting demonstrations of promising technologies; and promoting the implementation of best practices and emerging technologies that will contribute to the ITP goal of helping industry achieve a 30 percent reduction in energy consumption per unit of output by 2020. The objective of the Glass IOF is to reduce energy use in the glass industry by 49 trillion Btu per year by 2020.

The Glass IOF works in partnership with the Glass Manufacturing Industry Council (GMIC) on an ongoing basis to identify research priorities with broad applicability in the glass industry. The GMIC was established to represent the needs of the entire glass industry, bridging diverse interests and creating a unified voice. By partnering with GMIC and fostering collaboration with glass industry partners, the Glass IOF leverages public and private resources and ensures the application of research results.

The Glass IOF created the impetus for the industry to develop a long-term vision and roadmap. Glass IOF solicitations reflect the priorities in the vision and roadmaps, as well as ITP’s analysis of opportunities for energy savings, national priorities, and appropriate federal role. To assure broad participation among glass companies, glass IOF solicitations are announced via email to the GMIC listserv, in trade society publications, Web sites, meetings, the *Commerce Business Daily*, *FedBizOpps*, and the Glass IOF Web site. Selection of projects follows merit-based criteria that emphasize projected energy, environmental, and economic benefits based on sound analysis using a standardized procedure available in the on-line Project Evaluation Tool (<http://www.energetics.com/glasstool>). This rigorous solicitation development and implementation process ensures targeted, competitive solicitations for pre-competitive R&D.

The Glass IOF strategy is designed to have the greatest impact on reducing glass industry energy intensity. The strategy evolves over time as R&D projects are funded and completed, as new opportunities to have a significant impact on the industry are identified, and as national priorities change. The Glass IOF organizes its activities into four categories: next generation melting systems, energy efficiency performance improvements, advanced processing and environmental R&D, and technology validation. Exhibit 4 shows the target areas for each of these research categories.

GMIC

The Glass Manufacturing Industry Council (GMIC) is a trade association of the U.S. glass industry that includes among its members representatives of all four sectors: Flat, Container, Fiber, and Specialty. GMIC, incorporated in September 1998, is moving forward on a broad front to promote the interests and growth of the U.S. glass industry as a whole. Its formation represents a milestone development for the industry. Other industries (steel, aluminum, forest and paper products, etc.) have had organizations that operated on behalf of the entire industry and that were effective in consolidating benefits for the industry as a whole. Until the formation of the GMIC, the U.S. glass industry has had no “umbrella” body to represent its interests.

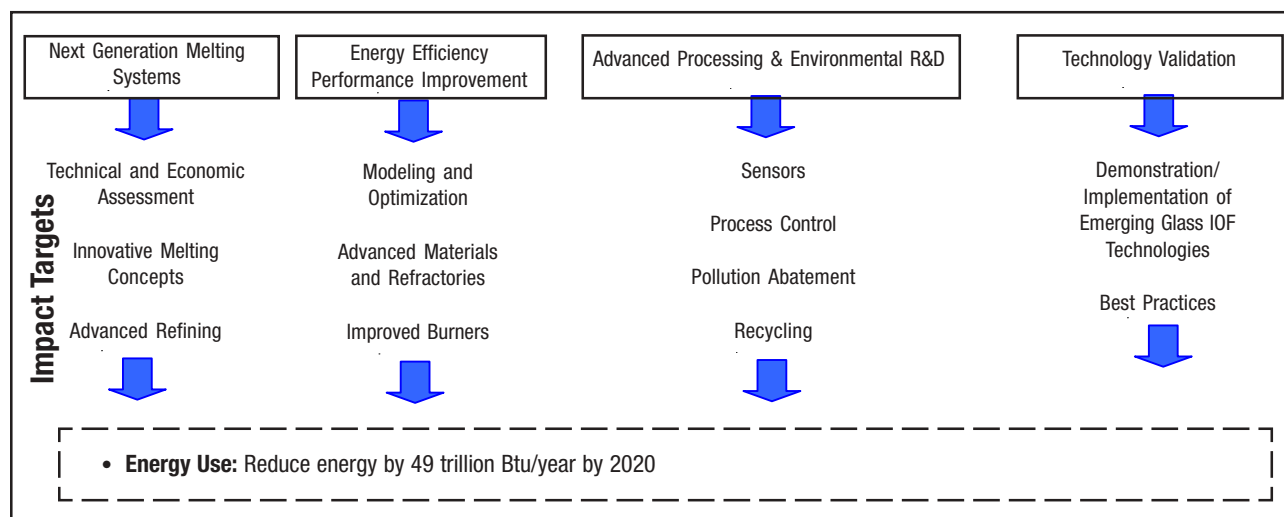
The mission of the Glass Manufacturing Industry Council is:

“To facilitate, organize, and promote the interests and growth of the U.S. glass industry through cooperation in the areas of technology, productivity and the environment.”

GMIC Members

Core	Associate
CertainTeed	Advanced Manufacturing Center
Corning, Inc.	Air Liquide America
Fire and Light Originals L.P.	BOC Gases
Johns Manville	Center for Glass Research
Leone Industries	Eclipse/Combustion Tec
Longhorn Glass	Gas Technology Institute
Owens Corning	Mississippi State University (DIAL)
Osram Sylvania	Pacific Northwest National Laboratory
PPG Industries (fiberglass)	Praxair, Inc.
Saint-Gobain Containers	Siemens Energy & Automation
Saint-Gobain Vetrotex America	Unimin Corporation
Schott Glass Technologies	U.S. Borax
Society for Glass Science and Practices	Westinghouse Savannah River Company
Technoglas	
Visteon	

Exhibit 4 Process and Technology Improvements Target Energy Efficiency



The Glass IOF portfolio underwent a significant transformation in FY 2003 in response to the EERE reorganization. In FY 2003, the glass portfolio began a transition to fewer, yet higher-risk, higher-impact research projects that will have the opportunity to produce revolutionary improvements in glass processing efficiency. Furthermore, a large percentage of projects in the portfolio will end in FY 2004. To leverage available funding, the Glass IOF submitted topics to the Small Business Innovation Research and Small Business Technology Transfer Program (SBIR/STTR) and tracks and manages SBIR/STTR glass projects. Topics selected for funding in FY 2003 include sensor, communication, and control technologies for energy efficiency. The Glass IOF also encourages other Industrial Technologies Program elements and other EERE programs to fund R&D priorities of the glass industry. For example, several sensors and automation and industrial materials projects are of great interest to the glass industry.

The glass portfolio includes projects and activities ranging from high-risk, high-return R&D and applied research and development, to demonstrations and technology delivery activities. Most R&D projects in the portfolio address technical needs in multiple glass industry segments. The length of projects ranges between 2-5 years. DOE generally contributes between 30 and 50 percent of the funds for each R&D project. R&D is conducted by glass companies, national laboratories, research institutes, and universities. Industry involvement accelerates the dissemination of research results and technology transfer. The portfolio also includes activities to highlight available opportunities that can immediately reduce glass energy industry use.

Project participants and partners are distributed across the United States, with the majority in areas densely populated with glass industry manufacturing facilities, such as the Midwest and Mid-Atlantic states, and at national laboratories. The map shows the distribution of the 41 Glass IOF partners (FY 2003).

FY 2003 Glass IOF Partners



FY 2003 HIGHLIGHTS AND ACCOMPLISHMENTS

The Glass IOF supports a diverse portfolio of cost-shared, pre-competitive research that addresses the most pressing and widespread industry needs. In fiscal year 2003, the Glass IOF included 13 core R&D projects. Of these 13 projects, six were completed and three projects were added to the portfolio in FY 2003. These projects are listed below, along with current Glass Project Laboratory User Services projects, one project concerning states, and two SBIR projects. In addition, over 20 projects that are relevant to the glass industry but are funded by other EERE programs are included in the Glass IOF portfolio.

Fact sheets describing projects in the Glass IOF portfolio are located at <http://www.oit.doe.gov/glass>.

R&D Highlights

Three New Awards Underway - Three new projects were negotiated and awarded through a competitive solicitation. Two of the three new awards are high-risk projects that involve developing innovative glass melting techniques that could significantly reduce energy and capital requirements. A merit review committee evaluated 21 proposals from the Glass IOF solicitation in January 2003 and made recommendations to DOE for project funding. All three projects are underway.

Technology Transfer Efforts for Advanced Glass Furnace Model Begin - Validation studies on the second version of the glass furnace model developed by Argonne National Laboratory continued at five participating companies. The more robust, final version of the code is now operational, and additional validation studies are being conducted. A technology transfer workshop was held to introduce the code to the glass industry, and licensing discussions have also been conducted.

High-Luminosity, Low-NO_x Burner Undergoes Additional Field Testing - Commercial-scale versions of the high-luminosity, low-NO_x burner developed by the Gas Technology Institute and Combustion Tec underwent long-term evaluation. An oxy-fuel fired fiberglass furnace was fully outfitted with several of the commercial-scale burners. In addition, another long-term test is ongoing on an oxy-fuel fired flat glass furnace fully outfitted with the burners through a NICE³ grant. While detailed results are not yet available, performance has predominantly met expectations for energy savings and emissions reductions. The burner should be commercially available in FY 2004.

Furnace Energy Assessment Best Practice Under Development - An energy assessment protocol for oxy-fuel firing optimization is nearing completion. Measurements have been completed and data analysis is underway. Several opportunities have been identified that can help optimize furnace operations and reduce energy consumption.

Glass Melt Properties Data Available - Technology transfer of glass property data developed by the Center for Glass Research (CGR) has begun. The data can greatly improve the effectiveness and robustness of mathematical modeling in the glass industry. The need for this data was accelerated by the industry adoption of oxy-fuel firing and furnaces operating at higher temperatures. Glass composition ranges and examples of measurement results can be found on the CGR Web site at <http://cgr.alfred.edu/meltprops/meltprops.html>.

Glass IOF Projects with Completed Government Funding in FY 2003

Advanced Process Control for Glass Production (Pacific Northwest National Laboratory, Thomson Consumer Electronics) - Pacific Northwest National Laboratory and Thomson Consumer Electronics developed and implemented an advanced process control system that should increase the amount of high-quality product from the initial manufacturing step. The system integrated (1) a model that relates process parameters (e.g., temperature, deformation, cooling rate) to final product quality; (2) a suite of novel, 3-D stress and temperature sensors for measuring process parameters; (3) a system for integrating and analyzing data from a wide range of sensors; and (4) cognitive control software for adjusting the process parameters to maintain product quality.

Auto Glass Process Control (Pacific Northwest National Laboratory, Visteon, PPG Industries) - This project developed a novel non-contact stress measurement method for improving quality control of automotive glass. A patent has been submitted for the method. In addition, a computer code for glass product forming was validated. Pacific Northwest National Laboratory is working with a software vendor to include the code in their commercial software program.

Development of an Energy Assessment Protocol (PPG Industries, Mississippi State University, Eclipse/Combustion Tec) - The objective of this project was to monitor and characterize furnace operations, identify potential energy inefficiencies, recommend energy-saving changes, and implement changes and re-evaluate energy consumption in order to optimize oxy-fuel firing in glass furnaces.

Diagnostics and Modeling of High-Temperature Corrosion of Superstructure Refractories in Oxy-Fuel Glass Furnaces (PPG Industries, Sandia National Laboratories, Gallo Glass, American Air Liquide, BOC Gases, Monofrax, NARCO/Harbison-Walker Refractories, Pennsylvania State University, University of Missouri-Rolla) - Researchers worked to identify factors controlling refractory corrosion in oxy-fuel glass furnaces, developed models to predict corrosion rates based on these factors, and developed in-situ optical techniques to monitor gas-phase alkali concentrations in glass furnaces. Efforts are continuing to ensure sub-routines for corrosion modeling are included in glass furnace models.

In-House Recovery and Recycling of Glass from Glass-Manufacturing Waste (Argonne National Laboratory, CertainTeed Corporation, Saint-Gobain Vetrotex America) - Argonne National Laboratory, CertainTeed, and Vetrotex America evaluated a separation technology for purifying and upgrading glass waste streams. Researchers studied imperfections and tested thermal and chemical methods to purify and upgrade the waste glass. An economic evaluation was conducted to ensure that the most technically efficient and cost-effective method is chosen for further process development.

Modeling of Glass Making Processes for Improved Efficiency: High Temperature Melt Property Database (Center for Glass Research, Corning Energy Laboratory Services, Thermex, Pacific Northwest National Laboratory) - This project developed data for modeling glassmaking processes. The properties of interest included thermal conductivity, thermal diffusivity, specific heat, density, surface tension, viscosity, electric conductivity, gas solubility, diffusion coefficients, and elastic constants all in the temperature range of 700° C to 1,600° C.

Active Glass IOF Projects in FY 2003

Glass R&D Projects

Development and Validation of a Coupled Combustion Space/Glass Bath Furnace Simulation (Argonne National Laboratory, Techneglas, Owens Corning, Osram Sylvania, Libbey, Visteon, Mississippi State University, Purdue University) - Researchers are developing a validated glass melting furnace simulation model that incorporates innovative features. The combustion space and glass bath models will be coupled at their interface through the use of appropriate heat flux and temperature continuity conditions. The combustion space model will incorporate a rigorous treatment of the radiative heat transfer to the glass bath. A detailed treatment of the batch melt and foam zones will be incorporated. A detailed model for NO_x kinetics will be incorporated into the combustion space model.

Development/Demonstration of an Advanced Oxy-Fuel Fired Front-End System (Owens Corning, Osram Sylvania, Thomson, BOC Gases, Eclipse/Combustion Tec) - Scientists at Owens Corning are developing a novel, oxy-fuel fired front-end system. After laboratory design testing of burners and system control, the system will be demonstrated in a commercial fiberglass production plant.

Energy-Efficient Glass Melting: The Next Generation Melter (Gas Technology Institute, Corning Incorporated, PPG Industries, Owens Corning, Johns Manville, Schott Glass Technologies, CertainTeed Corporation, Fluent, Praxair, Eclipse/Combustion Tec, A.C. Leadbetter and Son) Researchers at the Gas Technology Institute are designing and fabricating a pilot-scale submerged combustion glass melter. Two series of tests will be performed, and product glass properties will be analyzed.

High-Intensity Glass Melter (Plasmelt Glass Technologies, LLC, Johns Manville, Advanced Glassfiber Yarns) - Plasmelt is developing a plasma-melting system that is generically suited to melting a large variety of glass compositions. A prototype system will be constructed and tested, and product quality will be evaluated.

Measurement and Control of Glass Feedstocks (Energy Research Company, PPG Industries, Oak Ridge National Laboratory, Fenton Art Glass Company) - Researchers at Energy Research Company are developing a probe based on laser-induced breakdown spectroscopy to measure the chemical makeup of glass feedstocks in real-time. The probe will quickly detect contaminants and batch nonuniformity in the raw materials and cullet. Artificial neural network software will be tested to provide high-speed analysis of data obtained by the probe.

Monitoring and Control of Alkali Volatilization and Batch Carryover for Minimization of Particulates and Crown Corrosion (Sandia National Laboratories, Gallo Glass) - Researchers at Gallo Glass and Sandia National Laboratories are collecting data to determine the conditions having the greatest influence on volatilization, batch carryover, combustion efficiency, and furnace efficiency. A prototype measurement instrument using laser-induced breakdown spectroscopy will be designed and built. A control strategy and system for minimizing alkali volatilization and batch carryover will be developed.

Process Optimization Strategies, Models, and Chemical Databases for On-Line Coating of Float Glass (PPG Industries, Sandia National Laboratories) - Sandia National Laboratories and PPG Industries are developing modifications to atmospheric pressure chemical vapor deposition to increase the efficiency of reactant utilization. Researchers are conducting detailed theoretical and experimental studies of the underlying deposition process. Computational models will then be developed that can predict defects in coatings.

GPLUS Projects

The **Glass Project Laboratory User Services (GPLUS)** project enables glass manufacturers to conduct small-scale scoping studies in collaboration with any of the DOE national laboratories. The activity is cost-shared by DOE and the glass manufacturer, and results are provided to the GMIC to enable technology transfer. GPLUS projects include:

- Application of Furnace Model to an Oxy-Fuel Furnace for the Production of Amber Glass (Longhorn Glass, Argonne National Laboratory, Metal Container Corp.)
- Foaming of E-Glass (PPG Industries, Pacific Northwest National Laboratory)
- High Temperature Thermocouple Study (Schott Glass Technologies, Idaho National Energy and Environmental Laboratory)
- Improvement of Oxy Fuel Burner Design/Operations (Owens Corning, Sandia National Laboratories)
- Laser Induced Laser Breakdown Spectroscopy (LIBS) as a Glass Melt Monitor (Corning, Sandia National Laboratories)
- mm Wave Diagnostics for Glass Fiber Drawing (Johns Manville, Pacific Northwest National Laboratory, Cleveland State University)
- Strength Data and Design Method for Tempered Automotive Glazing which is Subject to Stress Corrosion Cracking (Visteon, Pacific Northwest National Laboratory)
- TV Glass Surface Problems (Techneglas, Oak Ridge National Laboratory)

Projects with States

Improvement of Performance and Yield of Continuous Glass Fiber Drawing Technology (Cleveland State University, PPG Industries, Johns Manville, Schott Glass, U.S. Borax) - This project is applying Six Sigma quality methodology and fundamental glass science to reduce fiber breakage and resultant waste. During the project, instrumentation will be developed, simulation models will be employed, and the process will be investigated and optimized.

SBIR Projects

- An Optical Fiber Probe for the Measurement of High Temperatures (Hope Technologies, Inc.)
- Universal Photo-Acoustic Sensor System (Physical Optics Corporation)

Other ITP and EERE Projects Relevant to the Glass Industry

Advanced Industrial Materials Projects Relevant to Glass

- Advanced Nanoporous Composite Materials for Industrial Heat Applications
- Advanced Waste Energy Recovery Using Thermoelectric Energy Conversion Technology
- Crosscutting Industrial Applications of a New Class of Ultra-Hard Borides
- Development and Demonstration of Advanced Tooling Alloys for Molds and Dies
- High Density Surface Treatments of Refractories
- Thermochemical Models and Databases for High Temperature Materials Processing and Corrosion

Combustion Project Relevant to Glass

- Development of an Innovative Energy-Efficient High Temperature Natural Gas Fired Furnace

Inventions and Innovations Projects Relevant to Glass

- Development of a Novel Frequency-Selective Solar Glazing System
- Enabling Tool for Innovative Glass Applications
- Energy-Saving Method of Manufacturing Ceramic Products from Waste Glass
- High-Throughput Vacuum Processing for Innovative Uses of Glass
- Low-Energy Alternative to Commercial Silica-Based Glass Fibers
- Thermophotovoltaic Electric Power Generation Using Exhaust Heat

NICE³ Project Relevant to Glass

Clean, Efficient Glass Production Using High-Luminosity, Oxy-Gas Burners (PPG Industries, others) - This project is demonstrating a novel burner system for oxy-fuel fired glass furnaces. The high-luminosity, low-NO_x burner combines a preheating zone with two combustion zones to provide high heat transfer and more uniform temperature distribution to the glass. The combustion system will be installed on a float furnace. Several months of testing and analysis will be conducted to verify energy and environmental benefits.

Sensors and Automation Projects Relevant to Glass

- Diagnostics and Control of Natural Gas-Fired Furnaces via Flame Image Analysis Using Machine Vision and Artificial Intelligence Techniques
- Fiber-Optic Sensor for Industrial Process Measurement and Control
- Thermal Imaging Control of Furnaces and Combustors
- Tunable Diode Lasers Sensors for Monitoring and Control of Harsh (Combustion Environments)
- Wireless Telemetry for Industrial Applications

Partnership Highlights

In addition to sponsoring R&D, the Glass IOF achieved a number of noteworthy accomplishments in FY 2003. These accomplishments are described in the following paragraphs:

Allied Partnership Agreement Signed with GMIC - An Allied Partnership agreement was signed with the Glass Manufacturing Industry Council (GMIC) in June 2003. This agreement formalizes a relationship between DOE and GMIC that will lead to the implementation of numerous energy improvement technologies and techniques across the glass industry. The GMIC has already hosted two energy efficiency training workshops, one on compressed air and one on process heating.



Resource CD-ROM Released - An updated resource CD-ROM for glass manufacturers was released. The CD-ROM provides tips and tools for spotting energy-saving opportunities in glass plants today as well as details on energy efficiency technologies.

Technical and Economic Assessment for Next Generation Melting Systems Drafted - This document, currently in draft, highlights technical and economic barriers that have stifled innovation and change in glass processes, including a detailed review of previous research efforts to improve glass melting and refining. The assessment will be published in FY 2004.

Glass Project Review Conducted - As part of ensuring stewardship of public funds, the Glass IOF conducts a yearly evaluation of research projects to assess performance, including progress towards technical, economic and market goals. The FY 2003 review was held in September 2003 at the National Renewable Energy Laboratory. About 75 representatives from all segments of the U.S. glass industry heard presentations about ongoing research projects being conducted by industry, university, and national laboratory researchers in order to evaluate each project's progress, significance, and relevance to the industry's needs.

Guidebook on Commercialized Energy Efficiency and Supply Technologies for the Glass Manufacturing Industry Drafted - This document, currently in draft, describes a variety of technologies that energy managers in the glass industry can use to make their plants more efficient, self-reliant, profitable, and less polluting. The guidebook will be published in FY 2004.

EERE Glass Review Board Formed - An internal EERE Glass Review Board was formed during FY 2003 to identify areas of common interest and better coordinate glass-related research activities throughout the programs within the DOE Office of Energy Efficiency and Renewable Energy. Posters from other glass-related activities were prepared and displayed at meetings and workshops, and a joint SBIR topic with EERE's Building Technologies program was submitted. Other EERE programs with significant ongoing activities include FreedomCAR and Transportation Technologies, and Distributed Energy and Electric Reliability.

Improving Energy Efficiency Today

Plant-Wide Assessments (PWAs) are cost-shared assessments of plant utility and process-related energy efficiency opportunities across a plant. To participate, plants submit a proposal to DOE as part of a competitive solicitation. In FY 2003, a PWA was conducted at an Osram Sylvania lighting plant, which identified energy saving opportunities of nearly 2 million kwh and 3 billion Btu of natural gas. Success stories from PWAs are available on the Best Practices Web site.

Disseminating Research Results to Industry

The Glass IOF conducts numerous outreach activities to disseminate R&D results and encourage companies to reduce energy intensity of glass processing. Project reports submitted to DOE are available on-line at DOE's Information Bridge Web site (www.osti.gov/bridge). In addition, the Glass IOF attended and participated in several trade shows and meetings in FY 2003, including:

- Glass Problems Conference
- American Ceramic Society Glass and Optical Materials Division Meeting
- 7th International Conference - Advances in Fusion and Processing of Glass
- Glass Industry Workshop: "Evolutionary and Revolutionary Strategies"
- Center for Glass Research Annual Meeting

Two commercial technologies supported by the Glass IOF continued to have great success in the U.S. glass industry. Oxy-Fuel Firing, commercialized in the early 1990s, now represents over 30 percent of U.S. glass industry capacity. In FY 2003, PPG Industries converted a second float glass furnace to oxy-fuel firing. The technology is saving over 4 trillion Btu annually industry-wide. Oxygen-Enriched Air Staging (OEAS), which provides a low-cost method for glass manufacturers to reduce NO_x emissions, was installed in four plants during FY 2003.

The Glass IOF also maintains an up-to-date Web site that provides additional information and highlights activities and opportunities.

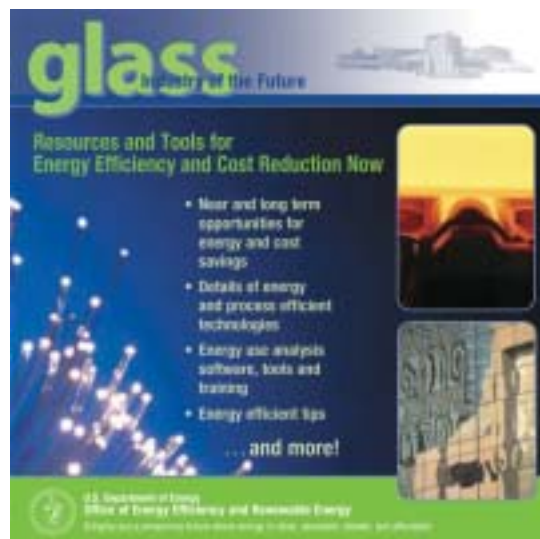
Energy Analysis - Targeting Energy Efficiency

The **Energy Footprint Study** of the Glass Industry, showing the flow of energy throughout the industry, was completed in FY 2003. The energy flow and losses are shown for energy supply, central energy generation/utilities, energy distribution, energy conversion, and process energy (see summary in Section 1).

The **Energy Bandwidth Study** was launched in FY 2003 to show the magnitude of energy savings possible for glass manufacturing. The energy "bandwidth" will be used to provide a rationale for supporting R&D on new technologies with the highest potential impact on glass industry energy consumption.

A **Project Evaluation Tool** was created to analyze energy and environmental benefits of glass research projects. Applicants to Glass IOF solicitations are now required to use the project evaluation tool.

The **Government Performance and Results Act (GPRA) Analysis** was completed for projects considered in the FY 2005 budget. The GPRA analysis estimates future benefits of emerging technologies in the glass portfolio based on market penetration, energy savings, and environmental emission reductions.



TOOLS, PUBLICATIONS, AND RESOURCES AVAILABLE

EERE offers valuable tools and publications to help glass companies improve productivity and energy efficiency. Some of these resources are described below. See the Web site at <http://www.oit.doe.gov/glass> for a complete listing.

Glass: A Clear Vision for a Bright Future - This landmark document released in 1996 outlines a vision for the glass industry in 2020, and identifies industry-wide goals for production efficiency, energy efficiency, environmental performance, and innovative uses.

Glass Industry Technology Roadmap - The GMIC published the *Glass Industry Technology Roadmap* in April 2002. The document describes technology challenges, research needs and priorities, and implementation roles.

Fact Sheets and Success Stories - These brief publications describe the objectives, benefits, partners, and accomplishments of RD&D projects in the Glass IOF portfolio.

Resource CD-ROM - The CD-ROM provides tips and tools for spotting energy-saving opportunities in glass plants today, as well as details on energy efficiency technologies. The CD-ROM contains over 200 documents relevant to glass manufacturers.



Energy and Environmental Profile of the Glass Industry - This detailed report benchmarks the energy and environmental characteristics of key technologies used in major processes of the glass industry.

HOW TO GET INVOLVED AND CONTACT INFORMATION

Partnership Information

Public-private partnerships are the foundation of ITP's technology delivery strategy. ITP includes its partners in every phase of the technology development process to focus scarce resources where they can have the greatest impact on industrial energy efficiency. To learn more, please visit our Web site at www.eere.energy.gov/industry.

- Collaborative, **cost-shared research and development** projects are a central part of ITP's strategy. Annual solicitations provide technology development opportunities in a variety of energy-intensive industries.
- **Industries of the Future Partnerships** increase energy efficiency in the most energy-intensive industries. In addition to cost-shared research and development projects, industry partners participate in the development of vision and roadmap documents that define long-term goals, technology challenges, and research priorities.
- **Allied Partnerships** provide an opportunity for ITP to reach a broad audience of potential customers by allying with corporations, trade associations, equipment manufacturers, utilities, and other stakeholders to distribute industrial energy efficiency products and services. By becoming an Allied Partner, an organization can increase its value to clients by helping them achieve plant efficiencies.
- **State energy organizations** work with ITP in applying technology to assist their local industries. ITP assists states in developing IOF partnerships to mobilize local industries and other stakeholders to improve energy efficiency through best practices, energy assessments, and collaborative research and development.
- **EERE's technical programs** (of which ITP is one of eleven) give manufacturers access to a diverse portfolio of energy efficiency and renewable energy technologies and bring advanced manufacturing technology to the renewable energy community. For more information, access the EERE home page at www.eere.energy.gov.
- The President's **Climate VISION** (Voluntary Innovative Sector Initiatives: Opportunities Now) effort also offers opportunities for manufacturers to pursue cost-effective actions that will reduce greenhouse gas emissions. See www.climatevision.gov for details.

Access to Resources and Expertise

The Industrial Technologies Program provides manufacturers with a wide variety of industrial energy efficiency resources to help your company cut energy use right away. Visit our site at www.eere.energy.gov/industry or call the EERE Information Center at 877-337-3463 to access these resources and for more information.

- ITP offers **energy management best practices** to improve energy efficiency throughout plant operations. Improvements to industrial systems such as compressed air, motors, process heat, and steam can yield enormous savings with little or no capital investment.
- Our suite of powerful system optimization **software tools** can help plants identify and analyze energy-saving opportunities in a variety of systems.
- **Training sessions** are held several times per year at sites across the country for companies interested in implementing energy-saving projects in their facilities. DOE software tools are used as part of the training sessions.

- ITP's qualified **industrial energy specialists** will work with your plant personnel to identify savings opportunities and train staff in the use of ITP software tools.
- Our extensive library of **publications** gives companies the resources they need to achieve immediate energy savings.
- **Plant-wide energy assessments** are available to manufacturers of all sizes interested in cutting their energy use. Cost-shared solicitations are available each year for plant-wide energy assessments. In addition, no-cost, targeted assessments are provided to eligible facilities by teams of engineering faculty and students from 26 university-based Industrial Assessment Centers around the country.
- The **DOE Regional Offices** provide a nation-wide network of capabilities for implementing ITP's technology delivery strategy. Regional Offices are located in Atlanta, Boston, Chicago, Denver, Philadelphia, and Seattle. Visit www.eere.energy.gov/rso.html for more information.

Where to Go to Get More Information

Visit our Web site - www.oit.doe.gov/glass

Learn about all EERE programs - www.eren.doe.gov

Ask an Expert - The Industrial Technologies Program's Clearinghouse is a great way to access ITP's resources. Clearinghouse staff members are available from 9 a.m. until 8 p.m. EST (6 a.m. until 5 p.m. PST).

Phone: 1-800-862-2086

Fax: 360-956-2214

Email: clearinghouse@ee.doe.gov

For print copies of DOE, EERE, and ITP Publications, contact -
Energy Efficiency and Renewable Energy Clearinghouse (EREC)

P.O. Box 3048

Merrifield, VA 22116

Fax: 703-893-0400

Phone: 800-363-3732

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and great energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as a vital new "energy carrier"

The Opportunities

Biomass Program

Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program

Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program

A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program

Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program

Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program

Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program

Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program

Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program

Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and business

Wind & Hydropower Technologies Program

Harnessing America's abundant natural resources for clean power generation

To learn more, visit www.eere.energy.gov

Glass Industry of the Future

Industrial Technologies Program

Boosting the productivity and competitiveness of U.S. industry



U.S. Department of Energy
Energy Efficiency and Renewable Energy

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